

Clear Air and Optical Turbulence in a Jet Stream in the Airborne Laser Context

Alex Mahalov and Basil Nicolaenko,
Departments of Mathematics and Mechanical & Aerospace Engineering, Arizona State University
Michael Adams, NAVO MSRC Visualization Center

The Airborne Laser Challenge Project supports the Airborne Laser (ABL) and the associated technology program by performing computer simulations of pertinent optical, clear air turbulence phenomenology and forecasting. The problems addressed include (1) the development, through Direct Numerical Simulation (DNS) microscale turbulence modeling, of improved turbulence parameterization models for use in mesoscale atmospheric codes such as MM5 for optical turbulence forecasting; and (2) an investigation and evaluation of the efficacy of existing turbulence parameterizations and improved closure relations in mesoscale weather prediction models in support of the ABL Atmospheric Decision Aid (ADA).

The intent of the project is that this improved forecasting capability will eventually be incorporated into the atmospheric decision aid currently being developed for operational use in deploying ABL assets. The main focus of the present study is to characterize variability and statistics of tropopausal turbulence at vertical scales $O(10m)$ - $O(100m)$ in the ABL context. These scales are unresolved in mesoscale meteorological codes, and the turbulent dynamics on these scales is poorly understood.

The simulations discussed here are being conducted at the Naval Oceanographic Office Major Shared Resource Center (NAVO MSRC) on the IBM POWER4, MARCELLUS.

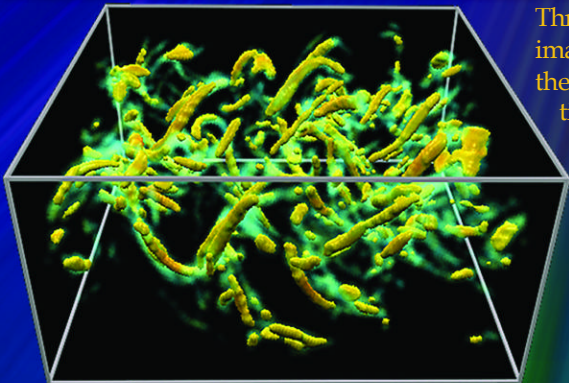
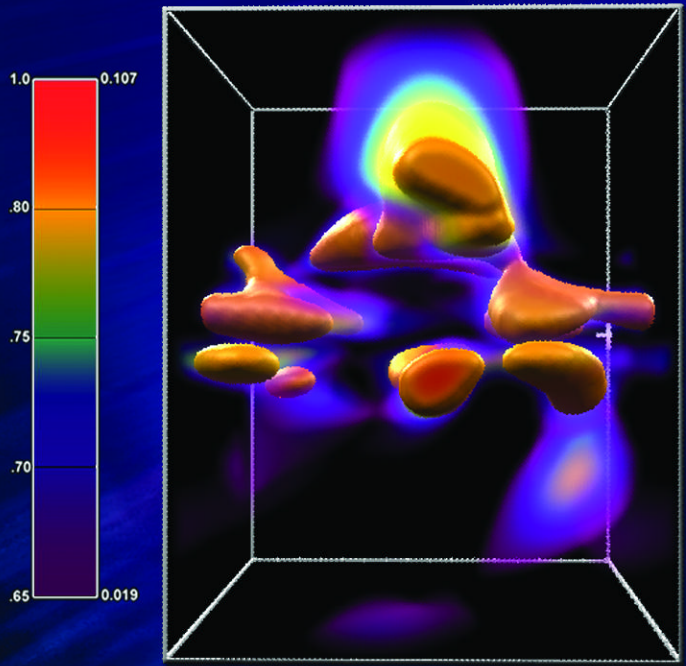
Though poorly understood, vertical scales $O(10m)$ - $O(100m)$ are crucial for forecasting both Clear Air Turbulence (CAT and optical turbulence. The wind shear) associated with jet streams acts as a major source of clear air turbulence on these scales. Also, it is now well-known that the lower stratosphere, with its characteristic stably stratified conditions, can support persistent layering (sheets of strong optical turbulence) even up to vertical scales $O(1m - 10m)$ and relatively large horizontal extent,¹⁻³ the implication being that

one should use very high vertical resolution in numerical studies. Vertical scales controlling the size of "sheets" in the atmospheric temperature field have been evidenced in the analysis of field measurements; the main dynamical properties of such layers, whether strongly mixed or not, can be characterized not only by Ri_g , but also by various outer scales of turbulence as shown by Alisse and Sidi.⁴ In Joseph et al.⁵ the existence of multiple branches in the scaling of turbulence quantities across the jet stream is demonstrated.

The robustness of multiple branches, with respect to DNS at doubled resolution (1,024 vertical levels), is also demonstrated. These issues of multiple scalings can be expected to be crucial for motivating appropriate parameterizations of turbulence associated with tropopause jet stream for the ABL-ADA.

Atmospheric optical turbulence is defined as temporal and spatial fluctuations of the index of refraction. While it is most obviously manifested by the twinkling of stars, it also is a major source of performance degradation for optical system.⁶ Optical turbulence is not identical to CAT, but it is intimately related since temperature and velocity fluctuations are strongly coupled.⁷ The most important quantification of optical turbulence for optical propagation calculations is the refractive index structure constant C_n^2 , a crucial parameter in electromagnetic wave propagation studies. For the upper troposphere and above, C_n^2 is usually parameterized as:⁸⁻⁹

$C_n^2 = \frac{0.165}{M^2} \left(\frac{L}{z} \right)^{5.5} \left(\frac{z}{L} \right)^{5.5}$ where λ is a constant (1.1) (generally taken as 2.8), L is an outer length scale for turbulence (this article collectively refers to all length scales above the Kolmogorov viscous dissipation (inner) scale as outer scales), and M is the gradient of the



Three-dimensional images of the absolute vorticity field.

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